REMARKS/ARGUMENTS

Claims 1-6 are pending herein. Claim 1 has been amended as supported by Fig. 1, for example, and to correct matters of form only. Claims 2-6 have been amended to correct matters of form only. Applicant respectfully submits that no new matter has been added.

1. The Examiner's suggestion to review the specification is noted. The specification has been amended accordingly and a Substitute Specification (Appendix A) is filed herewith.

2. Claims 1-3, 5 and 6 were rejected under §103(a) over Gilbreth in combination with Luongo. To the extent that this rejection might be applied against amended claim 1, it is respectfully traversed.

Pending claim 1 recites a high-temperature secondary battery based energy storage and power compensation system wherein, when operating normally, A.C. power is supplied directly from the electric power supply system (A.C. source) to the electric load. See Fig. 1, for example. Conversely, Gilbreth teaches that power from A.C. power sources is first converted to D.C. power in order to provide power from various sources to a D.C. power bus. D.C. power from the bus is then converted to A.C. power prior to application to the load. Gilbreth therefore, does not teach that A.C. power is supplied directly from the A.C. source to the load, as recited in pending claim 1.

For at least the foregoing reasons, Applicant respectfully submits that claim 1 and all claims dependent therefrom define patentable subject matter over the applied references.

With respect to the dependent claims, the PTO argued that Applicant has not disclosed that the use of a high temperature battery is for any particular purpose or serves a specific function and that the system would work with any high density, high discharge device. Further, the PTO argued that it would have been obvious to one of ordinary skill in the art to provide a battery with a power output of 3 to 8 times the load leveling or peak shaving level. However, the capability to output a compensation electric power of 3 to 8 times the rated electric power of the electric energy storage system as recited in claim 3 is due not only to the use of sodium sulfur batteries (claim 2), but also due to the method of controlling the output of the energy storage and power compensation system as described in the specification. Specification paragraphs [0036]-[0037] and Figs. 9 and 10 show that, under proper control the sodium sulfur battery can provide five to six times its normal rated current during discharge for up to an eight hour period and three to eight times its normal

rated current discharge when compensating for a voltage sag or service interruption (see also paragraph [0007] of the specification).

Therefore the compensation electric power of 3 to 8 times a rated electric power as recited in claim 3 is not the optimum or workable range as argued by the PTO, but rather a capability of the system derived from the use of the sodium sulfur battery and the method of control. None of the cited references teach or suggest the desirability of generating a compensation electric power beyond the rated power of the system, let alone the means to do so.

For at least the foregoing reasons, Applicant respectfully submits that all pending claims define patentable subject matter over the applied references, and thus, are in condition for allowance.

3. Claim 4 was rejected under §103(a) over Gilbreth in combination with Luongo and further in view of Paul. As claim 4 depends from claim 1, Applicant respectfully submits that claim 4 is also in condition for allowance for the reasons explained above.

Applicant respectfully submits that this application is in condition for allowance. Accordingly, the Examiner is requested to issue a Notice of Allowance as soon as possible.

If the Examiner believes that contact with Applicant' s attorney would be advantageous toward the disposition of this case, the Examiner is herein requested to call Applicant' s attorney at the phone number noted below.

The Commissioner is hereby authorized to charge any additional fees associated with this communication or credit any overpayment to Deposit Account No. 50-1446.

Respectfully submitted,

December 19, 2003
Date

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HIGH-TEMPERATURE SECONDARY BATTERY BASED ENERGY STORAGE AND POWER COMPENSATION SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a high-temperature secondary battery based energy storage and power compensation system.

Description of the Related Art

[0002] Conventionally, various energy storage systems for carrying out a peak shaving function as well as a load leveling function have been proposed. Although the proposed systems have been put into practical use in pumped storage hydro, none of the proposed systems has a power compensation function for compensating for a voltage sag or a service interruption, all of which are likely to happen suddenly in power supply systems.

[0003] Various electric power quality stabilizing apparatus formed by using semiconductor electric power conversion apparatuses capable of inhibiting harmonic distortion as well as voltage fluctuations have also been proposed. In fact, these electric power quality stabilizing apparatuses have been practically used in active filters and static Var compensator(SVC). Furthermore, to compensate for voltage sag and service interruption, UPSs have been

proposed and have already been put into practical use. However, none of the apparatuses mentioned above has a peak shaving function or a load leveling function.

SUMMARY OF THE INVENTION

[0004] The present invention ~~has been accomplished in order to solve~~ relates to a system which solves the above problems~~, it~~. It is an object of the present invention to provide an economical, high-temperature secondary battery based energy storage and ~~a~~ power compensation system which has a peak shaving function and a load leveling function, as well as an electric power quality stabilizing function.

[0005] According to the present invention, there is provided a high-temperature secondary battery based energy storage and power compensation system, comprising~~:~~

~~———~~ an electric power supply system~~;~~

~~———~~, an electric load~~;~~

~~———~~, and an electric energy storage system including a high-temperature secondary battery and a power conversion system (PCS~~),~~).

~~wherein~~ In the preferred embodiment, the electric power supply system, the electric load and the electric energy storage system are electrically connected, and ~~from which,~~ when operating normally, electric power is supplied to the electric load -while the electric energy storage

system operates to effect peak shaving running and load leveling running.~~; and~~

In addition, a high speed switch is provided between the electric power supply system and the electric energy storage system such that ~~:~~ when a voltage sag or a service interruption occurs in the electric power being supplied from the electric power supply system, the voltage sag is immediately detected, the circuit is temporarily shut off~~,~~ and electric power is immediately supplied from the electric energy storage system to the electric load in order to compensate for the voltage sag or the service interruption.

【0006】 Further, according to the present invention, the high temperature secondary battery is preferably a sodium sulfur battery.

【0007】 Moreover, ~~according to the present invention, it is preferred that~~ in the preferred embodiment the energy storage system ~~for~~ compensating for a voltage sag or a service interruption is a system capable of outputting a compensation electric power which is 3 to 8 times the rated electric power of the peak shaving running and the load leveling running.

【0008】 In addition, according to the present invention, it is preferred that a back-up generator is connected to a circuit on the electric power compensation side of the high

speed switch. ~~,~~ Additionally, a voltage compensation controller is provided which is capable of detecting a circuit shut-down effected by the high speed switch, sending a command in accordance with the detection signal to cause the energy storage system to discharge electric power required by the load ~~a load entire electric power~~, and at the same time starting the back-up generator. Thereby ~~, so that~~ if the electric power supply is not restored within a predetermined time period, the back-up generator is connected in parallel with the system, while at the same time the electric power supply from the energy storage system is stopped.

[0009] Furthermore, according to the present invention, it is preferred that an electric power supply system ~~comprising an electric power supply system, an electric load, and an electric energy storage system including a high-temperature secondary battery and a PCS; all of which being electrically connected with one another so as to supply an electric power from the electric power supply system to the electric load under normal operation conditions, and operating the electric energy storage system in order to effect peak shaving running and load leveling running; wherein said system~~ further comprises a control function capable of coping with a fluctuation derived from an accident such as a spike ~~and~~ or a frequency fluctuation in

the electric power~~,~~ by detecting immediately such an accident, and sending a signal based on detection to the electric energy storage system in order to compensate for the fluctuation.

[0010] Moreover, according to the present invention, it is preferred that spare high-temperature batteries connected in parallel with the module batteries are provided so as to ~~cope with~~ compensate ~~a case when the module batteries fail,~~ by switching module batteries to the spare batteries in a case when the module batteries fail.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Fig. 1 is a schematic view showing one embodiment of the high temperature secondary battery based energy storage and power compensation system formed according to the present invention.

Fig. 2 is a graph showing the ~~contents of the~~ load leveling running effected by using the energy storage system of the present invention.

Fig. 3 is a ~~graph~~ graphic showing how a voltage sag is prevented when the service interruption occurs in an electric power supply system ~~is prevented~~ by using the high-temperature secondary battery based energy storage and power compensation system formed according to the present

invention.

Fig. 4 is a graph showing how a load current having a deformed wave is compensated for in an electric power supply system ~~is compensated for~~ by using the high temperature secondary battery based energy storage and power compensation system formed according to the present invention.

Fig. 5 is a schematic view showing an example ~~(1)~~ of another embodiment of the high-temperature secondary battery based energy storage and power compensation system formed according to the present invention.

Fig. 6 is a graph showing how an output fluctuation of an electric power generated by a renewable energy is compensated for, by using the high temperature secondary battery based energy storage and power compensation system formed according to the present invention.

Fig. 7 is an explanatory view schematically showing an example ~~(2)~~ of another embodiment of the high temperature secondary battery based energy storage and power compensation system formed according to the present invention.

Fig. 8 is a graph showing how an output fluctuation of an electric power sent from a power supply system is compensated for by using the high temperature secondary battery based energy storage and power compensation system

formed according to the present invention.

Fig. 9 is a circuit diagram demonstrating a short-time high-output function of a sodium sulfur battery.

Fig. 10 is a graph showing a short-time high-output characteristic of the sodium sulfur battery.

Fig. 11 is an explanatory view showing in detail an example in which the high-temperature secondary battery based energy storage and power compensation system formed according to the present invention is used in an electric load (factory).

Fig. 12 is an explanatory view showing in detail an example in which the high-temperature secondary battery based energy storage and power compensation system formed according to the present invention and including spare batteries are used in an electric load (factory).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] The present invention will be explained in detail by referring to the embodiments described below. However, it is to be understood that the invention is not limited to these embodiments.

[0013] At first, the invention will be described in accordance with Fig. 1 which represents one embodiment of the present invention.

[0014] Fig. 1 shows a high-temperature secondary battery

based energy storage and power compensation system. As shown in the drawing, the energy storage and power compensation system comprises an electric power supply system 1, a load 2, and an energy storage system 5, which are all electrically connected to one another. The energy storage system 5 includes a high-temperature secondary battery 3 and a PCS 4. A high speed switch 6 is provided in the circuit between the electric power supply system 1 and the electric energy storage system 5. Further, in a circuit formed between the high speed switch 6 and the load 2, a high temperature secondary battery based energy storage and power compensation system 8 equipped with a back-up generator 7 is provided. A transformer 9 is provided on the AC side of the PCS 4, while a circuit breaker 11 is provided in connection with the back-up generator 7.

[0015] The high-temperature secondary battery based energy storage and power compensation system 8, which is constructed in accordance with the present invention, is usually employed to supply electric power from the electric power supply system 1 to the load 2. On the other hand, as shown in the graph of Fig. 2, the energy storage system 5 is operated in order to charge the high temperature secondary battery 3 with electric power at night, that is during the period from 10 PM to 7 AM. In this way, it is possible to perform so-called load leveling running in which the stored

electricity can be discharged during the day time when a relatively large amount of electricity is required, as well as so-called peak shaving running in which the stored electricity can be discharged during the period from 1 PM to 3 PM in summer when a relatively large amount of electricity is required.

[0016] In Fig. 2, the broken line shows the load curve ~~of~~ during one day, and the solid line shows the electric power supply from the grid during one day. During the period of 10 PM to 7 AM, some of the electric power ~~in the night~~ is used to charge a sodium sulfur battery 3 in the electric energy storage system 5. Conversely, during the period from 8 AM to 6 PM, an amount of the stored electricity is discharged from the electric energy storage system 5 in order to meet the demands corresponding to the increased electric load during this period of time~~, thereby~~. Therefore, the ~~reduction in a~~ maximum amount of electric power ~~in the~~ supplied by the electric power supply system can be ~~attained~~reduced.

[0017] ~~In the case where a~~The sodium sulfur battery which is used as a high-temperature secondary battery~~, the sodium sulfur battery~~ not only has a high density and a long usable lifetime, but also can produce a high output within a short time period and has a high speed response. Furthermore, the electric energy storage system using the

sodium sulfur battery can be fully automated. Moreover, since the electric energy storage system 5 is completely sealed, maintenance is easy. ~~In this way, the~~The electric energy storage and power compensation system 8 according to the present invention is characterized in that it uses a sodium sulfur battery. However, such a high-temperature secondary battery may also be a sodium·metal chloride battery.

[0018] Usually, whenever a voltage sag ~~occurs~~ in the electric power being supplied from the electric power supply system 1 or a service interruption occurs, ~~such an accident affects adversely on~~ there is an adverse effect on the electric load 2. In particular, when the electric load 2 is an important piece of production equipment controlled by computer, such a momentary voltage drop can cause ~~a considerably severe~~ considerable damage to the production system.

[0019] ~~In order to properly deal with a situation in which a voltage sag or a service interruption occurs, a~~A back-up generator is usually provided in an electric power supply circuit in order to properly deal with a situation in which a voltage sag or a service interruption occurs,. However, a problem still exists in that at least 10 seconds are required for the back-up generator to start supplying the necessary electric power to the electric load to

compensate for the sag or interruption.

[0020] The high temperature secondary battery based energy storage and power compensation system 8 according to the present invention is formed so that it can operate in the manner shown in Fig. 3. Namely, whenever there is a voltage sag in the electric power being supplied from the electric power supply system 1 or a service interruption occurs, the high speed switch 6 will operate to immediately ~~shut off the circuit~~disconnect the electric power supply system from the load, while at the same time ~~effecting a~~ providing temporary, full electric energy to the ~~instantaneous discharge of the entire electric~~ load from the electric energy storage system 5. Meanwhile, the generator is started, and there is an interval of about fifteen seconds~~,~~ before the entire load ~~electric power~~ is shifted to the generator. ~~In fact, the~~ The interval of about fifteen seconds can be compensated for by an electric power output from the electric energy storage system 5 utilizing the sodium sulfur battery.

[0021] As shown in Fig. 3, the high speed switch 6 operates at time t_1 to ~~shut off the circuit~~disconnect the electric power supply system from the load, and the electric energy storage system 5 utilizing the sodium sulfur battery will immediately start to supply ~~an~~ electric power to the load, and at the same time, the generator is started. Then,

about fifteen seconds later, i.e., at t_2, the generator 7 is fully ~~completely started~~ operational and the circuit breaker is ~~operated~~closed to connect the generator to the load. Afterwards, at t_3, the shift from the sodium sulfur battery to the generator is complete~~ly~~, thereby ending the electric discharge from the electric energy storage system 5.

[0022] On the other hand, in the case where a power compensation is needed only for a voltage sag, it is not necessary to use the back-up generator 7.

[0022.1] A semiconductor switch is preferably used as the high speed shut-off switch 6. This is because, whenever there is a voltage sag, the semiconductor switch can immediately ~~shut off~~disconnect the circuit and thus exhibits an excellent high speed response. If the circuit does not ~~shut off~~disconnect immediately, the electric power discharged from the energy storage system 5 utilizing a sodium sulfur battery having an excellent high speed response will undesirably flow back to the power supply system, rending it impossible to supply the required electric power ~~corresponding to a load electric power to be compensated~~ to the load.

[0023] Furthermore, it is possible to make use of the sodium sulfur battery system having a PCS. Namely, as shown in Fig. 4, the load current having a deformed wave can be improved to an overall load current without any distortion

by virtue of a distortion compensation output from the energy storage system 5 utilizing the sodium sulfur battery.

[0024] As described in the above, the energy storage and power compensation system 8 according to the present invention can, under normal operation, perform load leveling ~~running~~ as well as peak shaving ~~running~~. Meanwhile, the energy storage and power compensation system can instantly compensate for an entire electric load whenever there is a voltage sag or when a service interruption occurs, thereby protecting <u>an</u> important load or manufacturing system from severe damage. In addition, it is also possible to stabilize the quality of an electric power at each terminal of the system, as well as to effect an SVC running.

[0025] Fig. 5 is used to indicate one example ~~(1) serving as~~ <u>of</u> another embodiment for carrying out the present invention.

[0026] When electricity generating equipment 13 using renewable energy is provided in an electric power supply system located between a distribution substation 12 and an electric power user 2, the energy storage and power compensation system 8 formed according to the present invention can be operated to compensate for an output fluctuation of the generator 13.

[0027] That is, this embodiment is directed to an energy storage and power compensation system comprising an electric

power supply system 1, and an electric energy storage system 5 ~~being is~~ connected with said supply system and consisting of a sodium sulfur battery 3 and a PCS 4. Additionally, ~~characterized in that~~ an electric power compensation controller 14 is provided between the electricity generating equipment 13 and the electric energy storage system 5. This controller is capable of detecting an output from the generator 13 and outputting a signal to supply ~~an~~ electric power from the energy storage system 5 for compensating the output of the electricity generating equipment ~~is provided between the electricity generating equipment 13 and the electric energy storage system 5~~.

【0028】 Thus, the electric energy storage system 5 is capable of not only performing ~~a~~ load leveling ~~running~~ and ~~a~~ peak shaving ~~running~~, but also absorbing output ~~fluctuation~~ fluctuations derived from ~~a variation~~ variations in nature of the electricity generating equipment 13 involving the use of renewable energy ~~resource~~resources.

【0029】 Fig. 6 shows an example wherein an output fluctuation of the electricity generating equipment 13 equipped with a solar cell and a wind turbine generator ~~was~~ is compensated by outputting ~~a~~ power from the energy storage system 5 based on a signal from the electric power compensation controller 14 so as to ~~cope with~~compensate for the ~~fluctuation~~ fluctuations during the period of from 8 AM

to 6 PM.

【0030】 Fig. 7 shows an example ~~(2) serving as~~of a further embodiment for carrying out the present invention.

【0031】 The energy storage and power compensation system 8 according to this embodiment of the present invention ~~comprising~~ comprises an electric energy storage system 5 consisting of a sodium sulfur battery 3 and a PCS 4 ~~being~~ provided in a power supply system 1 ~~extending~~ which extends between the distribution substation 12 and the electric load 2~~;~~. This embodiment is further characterized in that an electric power quality stabilizing controller 15 capable of detecting the voltage, ~~the~~ current, and ~~the~~ frequency of ~~an~~ the electric power supplied from the power supply system 1 is provided between the electric power supply system 1 and the electric energy storage system 5~~, and also~~. The stabilizing controller 15 is capable of outputting power in proportion to deflections of the above parameters from the energy storage system 5, in accordance with detection signals,~~ is provided between the electric power supply system 1 and the electric energy storage system 5~~.

【0032】 Thus, the electric energy storage system 5 is capable of performing not only load leveling ~~running~~ and peak shaving~~ running~~, but also stabilizing operations in proportion to the electric power fluctuation. Therefore, it is possible to effect a desired compensation to ensure

stabilized power supply.

【0033】 Fig. 8 shows an example in which the controller operates to ~~obtain a compensation~~ provide compensating electric power from the energy storage system 5, so as to compensate for various fluctuations of ~~an~~ electric power flowing ~~to~~ from the electric power system 1, thereby ensuring a high quality electric power supply.

~~Examples~~

【0034】 Examples of the present invention will be described in the following.

Example 1

【0035】 ~~This example~~ Fig. 9 shows a short-time high-output function of the sodium sulfur battery.

【0036】 A sodium sulfur single cell battery (open-circuit voltage 2.075 V), a 28-mΩ resistor 17a, a 1-mΩ resistor 17b, and a switch 18 are connected in the manner shown in Fig. 9, thereby -forming a predetermined circuit. A rated discharge is performed ~~on~~ through the 28-mΩ resistor 17a, the switch 18 is opened or closed so as to effect a short-time high-output discharge ~~on~~ through the 1-mΩ resistor 17b. Fig. 10 (which is a graph) shows the result obtained when a high output discharge is repeated every hour during the rated discharge.

[0037] As shown in the graph, during 15 ~~second-output~~ and 30 ~~second-output~~second-outputs, it is possible to effect a discharge which is about 5 to 6 times greater than ~~a~~ the rated current (for eight hours). Namely, the sodium sulfur battery based energy storage and power compensation system formed according to the present invention is characterized in that it employs the above described sodium sulfur battery~~,~~ forming a system capable of performing ~~a~~ load leveling ~~running~~, as well as providing ~~a~~ the function of preventing an instantaneous voltage drop.

Example 2

[0038] Fig. 11 shows in detail an example in which the sodium sulfur battery based energy storage and power compensation system 8 formed according to the present invention can be used in an electric load (factory) ~~2~~ having a total load of 5 MW.

[0039] A energy storage system 5 including ten units of 500 KW PCSs 4 and sodium sulfur batteries 3 is electrically connected to a high speed semiconductor switch 6, an electric power supply system 1 and ~~an electric~~a factory load ~~2~~, in the manner shown in Fig. 11. Under normal operation, the energy storage system 5 receives at night an electric charge from the electric power supply system 1. However, ~~,~~ ~~but~~ during the daytime when there ~~are~~ is an increased ~~needs~~

need for electric power ~~because~~ due to a ~~lot of~~ heavier electric load ~~such as~~ created by the use of air conditioning equipment and air conditioners ~~are in use~~, the energy storage system 5 discharges 1 MW electric power, thereby ~~effecting~~ providing load leveling ~~running~~.

[0040] When there is a voltage sag or a service interruption, the high speed switch 6 operates to immediately ~~shut off~~ disconnect the ~~circuit~~electric power supply system, while at the same time an electric power of 5 MW is spontaneously discharged from the energy storage system 5 within 30 seconds, thereby ensuring ~~a~~ power ~~supply~~ is supplied having stabilized quality without any voltage drop, until the service interruption is over and ~~an~~ the ordinary power supply has been restored.

[0041] In Fig. 11, the discharge is indicated as a PQ discharge (Power Quality discharge). In the case where there is a back-up generator (not shown), 30 seconds would be sufficient to bridge the power source from the energy storage system to the back-up generator. Accordingly, even if the service interruption period is relatively long, it is still possible to supply ~~an~~ electric power to the electric load (factory) having a high and stabilized quality ~~to the electric load (factory) 2~~.

[0042] Fig. 12 shows in detail an example in which a group of spare batteries 19 are arranged for use with a

high-temperature battery system of the present invention, which is provided for an electric load having a total load of 10 MW. If, in the event of an accident, a module battery 3 has a failure, the failed group is ~~opened~~ disconnected while the spare group 19 ~~can be~~is connected in parallel to the circuit, thereby improving the reliability for supplying ~~an~~ electric power. In such a case, since each group includes 2 module batteries 3, if the system is used for a long time, and the second battery also fails, a healthy module battery of the failed group ~~(in opened condition)~~ can be used to replace the second failed battery. In this way, it is possible for the system to run for an extremely long time, ensuring ~~an~~ improved reliability.

[0043] As may be understood from the above description, the high-temperature secondary battery based energy storage and power compensation system formed according to the present invention, is a system capable of performing peak shaving ~~running~~ as well as load leveling ~~running~~, thereby ensuring an improved, stable, and high quality electric power supply. Therefore, the energy storage and power compensation system of the present invention is suitable not only for effectively making use of the electric power in the night time, but is also suitable for supplying ~~to a factory or the like facilities a~~ high quality electric power to a factory or like facility. Further, the energy storage and

power compensation system of the present invention is capable of preventing ~~an~~ a voltage sag in important equipment, stabilizing an output electric power generated ~~even~~ by fluctuating renewable energy, and ~~which is capable of~~ compensating for voltage and current ~~spike~~spikes, frequency fluctuations and harmonic distortions.